IEA OECD ETSAP

Recent ETSAP Modeling Activities with MARKAL-TIMES

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- The International Energy Agency (IEA-OECD): a forum for international collaboration in energy related fields
- From 1976 IEA member countries co-operate in the Energy Technologies Systems Analysis Project to:

- build the Technical Engineering Competitive Partial / General Equilibrium Modelling kits: MARKAL, TIMES
- improve the knowledge of energy systems technologies and their representation through models (RES)
- carry out policy analyses at the global, regional, national, local level

- China-ETSAP collaborations

IEA Collaborations relevant for energy modelling activities

- Times Series of National Energy Balances, uniform across member and non member countries
- Oil market studies and security of supply
- Long Term Co-operation activities on energy markets and energy related environmental problems
- Studies of countries energy systems and policies
- Sectoral energy technologies studies across countries
- Energy Research and Technologies collaboration (40 agreements among member / nonmember countries)

IEA member countries

- North America: Canada, Mexico, United States
- European Union: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden, United Kingdom
- Asia Pacific: Australia, Japan, S. Korea, New Zealand
- Other European Countries: The Czech Republic, Hungary, Iceland, Norway, Poland, Switzerland, Turkey

Uniform energy balance (China, 1997)

SUPPLY	Coal	Crude Oil	Oil Prod.	Gas	Nuc	Hydro	Comb. Ren.	Elec-tricity	Heat	Total
Indigenous Productio	686	161	-	21	4	17	208	-	-	**1097**
Imports	1	35	30	-	-	-	-	0	-	**66**
Exports	-26	-20	-7	-2	-	-	-	-1	-	**-56**
Intl. Marine Bunkers	-	-	-1	-	-	-	-	-	-	**-1**
Stock Changes	-6	-1	-3	-	-	-	-	-	-	**-10**
TPES	**655**	**175**	**19**	**19**	**4**	**17**	**208**	**-1**	**-**	**1096**
Transformations:	-	-	-	-	-	-	-	-	-	-
Statistical Differences	-17	-1	8	0	-	-	-	-0	-	**-10**
Electricity Plants	-229	-1	-16	-2	-4	-17	-	98	-	**-170**
CHP Plants	-29	-0	-4	-0	-	-	-	-	28	**-5**
Gas Works	-3	-	-1	3	-	-	-	-	-	**-0**
Petroleum Refineries	-	-166	168	-	-	-	-	-	-	**2**
Coal Transformation	-54	-	-	-	-	-	-	-	-	**-54**
Own Use	-36	-4	-16	-6	-	-	-	-16	-6	**-84**
Distribution Losses	-	-2	-0	-1	-	-	-	-7	-0	**-10**
TFC	**288**	**1**	**159**	**14**	**-**	**-**	**208**	**74**	**22**	**766**

Uniform energy balance (China, 1997)

CONSUMPTION	Coal	Crude Oil	Oil Prod.	Gas	Comb. Ren.	Elec-tricity	Heat	Total
TFC	**288**	**1**	**159**	**14**	**208**	**74**	**22**	**766**
INDUSTRY SECTOR	**204**	**1**	**40**	**10**	**-**	**49**	**17**	**321**
Iron and Steel	27	0	4	0	-	8	3	**41**
Chemical and Petroch	51	1	27	7	-	13	7	**106**
of which: Feedstock	*12*	*0*	*20*	-	-	-	-	**33**
Non-Ferrous Metals	5	0	1	0	-	4	1	**12**
Transport Equipment	3	0	0	0	-	2	0	**6**
Machinery	13	0	1	1	-	5	1	**20**
Mining and Quarrying	3	0	0	0	-	2	0	**5**
Food and Tobacco	14	0	1	0	-	3	1	**19**
Paper, Pulp and Printi	8	0	0	0	-	2	1	**11**
Wood and Wood Prod	2	0	0	-	-	1	0	**3**
Construction	2	0	1	0	-	1	0	**4**
Textile and Leather	10	0	1	0	-	3	2	**16**
Non-specified	3	-	0	0	-	1	0	**5**

Uniform energy balance (China, 1997)

CONSUMPTION	Coal	Crude Oil	Oil Prod.	Gas	Comb. Ren.	Elec-tricity	Heat	Total
TFC	**288**	**1**	**159**	**14**	**208**	**74**	**22**	**766**
TRANSPORT SECTOR	**7**	**-**	**65**	**0**	**-**	**2**	**-**	**74**
Air	-	-	5	-	-	-	-	**5**
Road	-	-	47	0	-	-	-	**47**
Rail	7	-	4	-	-	-	-	**11**
Pipeline Transport	-	-	0	-	-	-	-	**0**
Internal Navigation	-	-	9	-	-	-	-	**9**
Non-specified	-	-	0	-	-	2	-	**2**
OTHER SECTORS	**77**	**0**	**34**	**4**	**208**	**23**	**5**	**351**
Agriculture	10	-	11	-	-	6	0	**27**
Comm. and Publ. Ser	8	0	13	0	-	6	1	**29**
Residential	59	-	9	4	208	11	4	**295**
Non-specified	0	0	-	-	-	-	0	**0**
NON-ENERGY USE	**0**	**-**	**21**	**-**	**-**	**-**	**-**	**21**

International collaboration in Energy Research & Technologies

Energy Technologies Information Centres:

- **IEA Coal research, clean coal centre /www.iea-coal.org**
- **Energy Technology Data Exchange //www.etde.org.uk**
- **Energy and Environmental Technologies Info Centres:**

- **energy efficiency //www.caddet-ee.org**
- **renewables //www.caddet.co.uk**
- **GHG Technology Info Exchange //www.greentie.org**

- **International Centre for the Gas Technology Information - www.icgti.org**

International collaboration in Energy Research & Technologies

Fossil Fuel Technologies:

- **Coal Combustion Sciences**
- **Enhanced Oil Recovery**
- **Fluidised Bed Conversion**
- **Fossil Fuel Multiphase-Flow Sciences**
- **Greenhouse Gas R&D Program**

//www.ieagreen.org.uk

International collaboration in Energy Research & Technologies

Renewable Energy Technologies:

- Bioenergy //www.abdn.ac.uk/ieabioenergy
- Geothermal
- Hydrogen
- Hydropower Technologies
- Photovoltaic Power Systems
- Solar Heating and Cooling //www.arch.vuw.ac.nz/iea
- Solar Power&Chemical Energy Systems (SolarPACES)
- Wind Turbine Systems

International collaboration in Energy Research & Technologies

Efficient Energy End-Use Technologies:

- **Advanced Fuel Cells**
- **Alternative Motor Fuels**
- **Building and Community Systems //www.aivc.org**
- **Demand Side Management //www.iea.org/dsm-enef**
- **District Heating and Cooling**
- **Energy Conservation and Emission Reduction in Combustion**
- **Energy Storage**

International collaboration in Energy Research & Technologies

Efficient Energy End-Use Technologies (continuation):

- **Energy Technologies Systems Analysis Project ETSAP**
- **Heat Pumping Technologies www.heatpumpcentre.org**
- **Heat Transfer and Heat Exchangers**
- **High Temperature Materials**
- **High Temperature Superconductivity**
- **Hybrid and Electric Vehicles**
- **Process Integration Technology for Industry Systems**
- **Pulp and Paper**

International collaboration in Energy Research & Technologies

Nuclear Fusion Science and Technology

- Environmental, Safety and Economics Aspects of FP
- Fusion Materials
- Nuclear Technology of Fusion Reactors
- Plasma Wall Interaction in TEXTOR
- Reversed Field Pinches
- Stellarator Concept
- Three Large Tokamak Facilities
- Toroidal Physics in, Plasma Technologies of Tokamaks

The ETSAP collaboration (started in 1976)

- **Present participants:**

  Australia, Belgium, Canada, EU, Finland, Germany, Greece, Italy, Japan, S. Korea, The Netherlands, Norway, Sweden, Switzerland, United States

- **Main goals:**

- **to develop modelling tools that represent different systems of energy flows and technologies**
- **to improve the knowledge of global, regional, national and local energy and environment systems**
- **to contribute to the energy environment debate with quantitative and methodologically sound analyses**

First MARKAL model generator (1979)

(sometimes called marginal price generating model)

- fixed multi-time periods Pareto Optimal models minimising the discounted total system cost
- energy flows and technologies (energy system only)
- single region
- with price sensitive supply curves, non price sensitive demand curves expressed in final/useful energy terms
- time/Reference Energy System (RES) perfect foresight
- calculated trade-off curves among cost, energy security and emissions
- 2 versions of the code: FORTRAN and OMNI

Versions of MARKAL model generator

- MARKAL Materials, can represent tens of pollutants and in principle the whole economy
- MACRO, NLP general equilibrium version, with a single production function
- MICRO, NLP partial equilibrium version, with demand elastic to prices (own/cross)
- Stochastic to calculate optimal hedging strategies
- Elastic Demand, linearised partial equilibrium version
- Multi-regional, with endogenous trade
- Endogenous Technology Learning (MIP)

Recent Software Improvements

- automatic creation of a reference energy system from the IEA energy balances (TEMPLATE spreadsheets)
- projections of the demand for energy services from common drivers and own price elasticities
- common technologies repository, with efficiencies, emissions, materials use, costs and learning of existing and new technologies
- multiple model shells (MUSS, Answer, VEDA FE)
- multiple model generator programs (GAMS)
- multiple LP, NLP, MIP solvers
- multiple / flexible reporting tools (VEDA BE, Answer)

MARKAL/TIMES model generator today

- variable time periods length (TIMES) competitive partial equilibrium models maximising the discounted sum of the consumer and producer surplus
- models flow and technologies of energy systems + materials + wastes + pollutants + other sectors
- multi-grids, multi-regional with endogenous trade
- price sensitive supply and demand curves (free units)
- clairvoyant, or stochastic, or time-stepped
- In each market technologies with the best marginal benefit / cost ratio are chosen, including externalities
- coded in GAMS

Static equilibrium in MARKAL-TIMES

- hundreds of energy good and commodity markets are represented (from coal to passenger*km)
- the stepwise supply and demand curves of each market are calculated including independent investment, fixed, variable, fuel, environment, material costs (based upon separate variables)
- the equilibrium point in each market of the RES calculates Quantities, Prices and indicates both supply and demand marginal technologies
- the distance from competitiveness of each technology and the technology gaps for reaching the desired equilibrium points are calculated by the model

Dynamic equilibrium in MARKAL/TIMES

The reaction of the energy system to exogenous dynamic changes is represented in the model through

- starting point is the present stock of technologies and the possible future availability of well defined technologies (not upon past behaviour)
- substitution among competing and time improving processes commodities, similar to the mechanism of optimal Von Neumann multiple producers/multiple commodities I/O models (not through price dependent technical coefficients of a Leontief I/O square matrix)
- variable depreciation plans for investments

Recent studies with MARKAL models

- Impact of different schemes for international flexible mechanism for mitigation (Can-US-India-It, CH-Columbia, NL-CH-SW, Nordic Eu countries)
- Environmental effects of reducing/removing energy subsidies or of adding a Carbon Tax (Italy, Australia)
- National MARKAL models contribute to identify climate change mitigation options and the evaluation of climate change policies (Can, National Communic. to FCCC of Aus, Be, Cz, It, Latvia, NL, Sw, Us
- Effect of including in the energy system materials, full fuel cycle analysis and endogenous technology learning for mitigation strategies

Multi-regional Global Models

- US MARKAL+MERGE for other regions (DWI-Stanford)
- The Global Markal Macro Trade model with Endogenous Technology Learning (PSI-IIASA)
- The SAGE Project at the US Energy Information Administration (System to Analyse Global Energy markets) with Time Stepped Technology Learning
- The IEA Energy Technologies Perspectives Project adds technological insight to 2002 World Energy Outlook with a bottom-up multiregional global model
- Multi-regional Global TIMES (NRCanada, GERAD)
- Long time horizon multiregional global model for SERF3 (Socio Economic Research on Fusion)

Local energy environment planning

Under ETSAP and ALEP (Advanced Local Energy Planning, IEA IA on Energy Conservation in Buildings and Community Systems)

District energy grids expansion, waste management, local pollution vs global mitigation (local Agenda 21), energy conservation policies in buildings, public vs private transportation, local tax/subsidies

- Germany (Mannheim,
- Italy (Bologna, Torino, Aosta, Basilicata,
- The Netherlands (Delft,
- Sweden (Jancheping, Norcheping,
- Switzerland (Geneve,
- China (Hong Kong, etc.

China - ETSAP present collaborations

(download proceedings of Baden workshop, Oct. 2000)

China MARKAL models:

- **Tsinghua University - ABB - PSI (S. Kypreos)**
- **Tsinghua University - DOE - BNL (J. Lee, P. Tseng)**
- **Tsinghua University - Princeton - BNL (G. Goldstein)**

Provincial / Municipal MARKAL models:

- **Shandong, price elastic, ERI - ABB - PSI (S. Kypreos)**
- **Shanghai, by SAES - Dutch Gov. - ECN (K. Smekens)**
- **3 cities: Chongqing, Shanghai, Tianjin, by Tsinghua University - EU - ECN (K. Smekens)**

Possible future collaborations

- Organisation in Beijing (with the IEA support) of
  - a joint China-IEA seminar on Energy Balances to further discuss recent trends and improve their understanding
  - a joint China-IEA to present the status of global multi-regional and China energy models
  - a joint ERI-ETSAP workshop, exploring among others China and multi-regional global MARKAL/TIMES models
- Chinese Institutes/Organisations using MARKAL join next task sharing annex of ETSAP (2002-2004)
- Next ETSAP cost sharing annex supports development of MARKAL/TIMES China models (software, technol.db)
- Outreach funds contribute to revise the MARKAL/TIMES China models (why not a multi-regional China model, as in Canada?) and the characterisation of technologies

Visit ETSAP main web sites ..

- www.iea.org/
- www.ecn.nl/unit_bs/etsap/main.html
- www.crt.umontreal.ca/~amit/THEMODEL/
- www.ier.uni-stuttgart.de/
- www.kier.re.kr/
- www. abare.gov.au/
- www.tokai.jaeri.go.jp/
- etc.

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